Indexing Guidelines: Applications in Use of Pulmonary Artery Catheters and Pressure Ulcer Prevention

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ABSTRACT

In a busy clinical environment, access to knowledge must be rapid and specific to the clinical query at hand. This requires indices which support easy navigation within a knowledge source. We have developed a computer-based tool for trouble-shooting pulmonary artery waveforms using a graphical index. Preliminary results of domain knowledge tests for a group of clinicians exposed to the system (N=33) show a mean improvement on a 30-point test of 5.33 (p<0.001) compared to a control group (N=19) improvement of 0.47 (p=0.61). Survey of the experimental group (N=25) showed 84% (p=0.001) found the system easy to use. We discuss lessons learned in indexing this domain area to computer-based indexing of guidelines for pressure ulcer prevention.

INTRODUCTION

Clinicians need to manage a large body of knowledge, using about two million pieces of information. Rather than storing such information randomly, experienced clinicians organize it into scripts structured around common clinical problems. They then use pattern matching to recognize and manage these problems in patients [1]. Adding to this complexity, clinical guidelines have been disseminated and used with some success to influence clinician behavior and to improve patient outcome [2]. Leading this effort recently has been the Agency for Health Care Policy and Research (AHCPR), with guidelines on several topics including pressure ulcer prevention [3].

In order to assist clinicians in the management of this information, some workers have developed computer-based access to patient care guidelines [4]. However, when multiple computer-based knowledge sources are made available, difficulty with interfaces and applying knowledge from different sources limits the utility of such systems [5].

With these challenges in mind, we have developed a computer-based system for providing problem-based access to knowledge used in troubleshooting pulmonary artery catheter waveforms. We chose this topic because knowledge among clinicians of the use of such catheters is variable despite their widespread use [6].

In this development we synthesized a knowledge base from a number of sources in the published literature and the opinions of local domain experts. We have studied prospectively the user satisfaction and impact on domain knowledge of an initial experimental group of users compared to a control group which did not use the system. In addition, based on this experience, we have begun to implement a computer-based system for access to the AHCPR guideline for pressure ulcer prevention.

PULMONARY ARTERY CATHETER SYSTEM DESIGN

The pulmonary artery catheter waveform troubleshooting system is implemented in the Toolbook authoring environment, running under the Windows operating system. This provides a robust graphical user interface coupled with the facility to develop prototype software rapidly. Though we might have used an expert system shell to organize and manage this expert knowledge, the relative simplicity of the rules governing the advice displayed by the system obviated this use.

The expert information [7] is organized hierarchically as depicted in Figure 1. At the upper level of the hierarchy, the user must choose one

subtree of the hierarchy based on the anatomic location of the catheter: right atrium, pulmonary artery or pulmonary capillary wedge position. Once one of these large chunks of knowledge is chosen, the user then may access specific pieces of knowledge through the use of a graphical index. The user matches the catheter waveform of interest to one displayed by the system, selecting the one with the best match. Possible matches include topics such as damping, ringing and respiratory variation.

Level 0: *Anatomic site of the catheter tip*
        Right Atrium
        Pulmonary Artery
        Pulmonary Capillary Wedge

Level 1: *Problematic waveforms at a given catheter site*
        Catheter migration
        Damping
        Flat-line Pressure
        Irregular Rhythm
        Large Pulsations
        Normal Waveform
        Questionable Pressures
        Respiratory Variation
        Ringing

Level 2: *Description of Waveforms*
        Characteristics
        Causes
        Measurement
        Solutions

Figure 1. Hierarchy of knowledge of the pulmonary artery system. Each site at Level 0 is associated with each waveform of Level 1, each of which in turn is described by the four topics of Level 2.

The expert information pertinent to the selected waveform then becomes available to the user. This is organized in four categories: characteristics, causes, management and measurement. Each category then may be selected in turn to display information pertinent to identifying, isolating the cause of, improving and calibrating the problem with the catheter. A graphical design is used throughout, employing digitized waveform tracings, textual messages and digitized radiographs [7].

SYSTEM EVALUATION

The system was installed in a medical intensive care unit (ICU) which averaged three to five patients a day with pulmonary artery catheters in place. Another medical ICU was chosen as a control. The study group was the staff nurses of the ICUs and the resident physicians who rotated through these units each month. A total of 52 subjects agreed to participate in the initial study, including 33 in the experimental group (28 nurses and 5 physicians) and 19 in the control group (11 nurses and 8 physicians). All subjects provided written, informed consent.

The experimental group was those participants who worked in the ICU in which the system was installed. Each participant received an orientation to the system from one of the authors. The control group was those nurses and physicians working in a separate medical ICU which supported pulmonary artery catheters but in which the system was not installed. Data were collected over a period of ten months.

All participants completed a 30-question test of knowledge about pulmonary artery catheters before and after the study period. This instrument is based on a tool used to evaluate computer-based instruction systems as previously described [7]. In order to develop this test, the system designers created approximately 70 multiple choice, single-best-answer questions which could be answered by using the system. These questions were validated by administering the test to other local experts, and based on their responses and comments 30 of these questions were selected for the final version of the test.

In the case of the physicians who rotated through the units, these tests were completed before and after their exposure to the units. Although several physicians rotated through both control and experimental units during the study period, each was included in only one arm of the study, based on which unit was first in the rotation order.

In addition, 25 users in the experimental group completed questionnaires designed to evaluate satisfaction with various aspects of the system as previously described [7].

RESULTS OF EVALUATION

In the experimental group, the mean test score

before exposure to the system was 13.85 (out of a possible 30) and after exposure was 19.18 (p < 0.001 by two-tailed analysis). This represents a 38.5% improvement in the mean score. By contrast, the mean test score of the control group was 16.74 before the study period and 17.21 afterwards (p = 0.61 by two-tailed analysis), which is an improvement of only 2.8%.

Seventy-five percent (N = 25) of the experimental group completed a survey of computing satisfaction. Eighty-four percent found the system was always or almost always easy to use (p = 0.001 by one-tailed analysis). Ninety-six percent found the information provided by the system always or almost always accurate (p < 0.001). The format was found to be acceptable always or almost all of the time by 76% of respondents (p = 0.007).

APPLICATION TO PRESSURE ULCER PREVENTION

Cognizant of this experience of indexing a clinical guideline using a graphical interface to produce a positive change in clinician knowledge, we have begun to implement a computer-based index for the AHCPR guideline for the prediction and prevention of pressure ulcers in adults [3]. This area was chosen because of the significant prevalence of the problem [8] and the availability of a guideline written by a national organization. This successor system also uses a graphical interface to index guideline knowledge, but it relies principally on an interlinked hierarchy of important themes which we have termed the concept index.

As in the pulmonary artery catheter advice system, the pressure ulcer system is implemented in Toolbook in a Windows environment. However, because of the number and complexity of the rules governing expert advice on this topic, we use a commercial expert system shell, NEXPERT OBJECT, to manage and process a rule-based system. NEXPERT functions as an expert system server which communicates with the Toolbook client using a Windows Dynamic Link Library.

In this environment, we have structured the text of this guideline around a central concept index. Such an index combines the functionality of a glossary (containing simple definitions) with a table of contents (containing a hierarchy of concepts and their constituent subparts) and a hypertext document (containing multiple threads between

topics). This extends the hierarchical structure of the pulmonary artery system by allowing navigation between topics without necessarily traversing to a common node located above both topics in the hierarchy. The concept index superficially resembles the main menu of many computer-based education programs but extends this notion by permitting more robust navigation than such programs.

To create this concept index, we manually reviewed the guideline document and divided this knowledge into "chunks" such as friction and shear, mobility and moisture exposure. Each concept has a simple definition, like that which would appear in a glossary, but it also contains hierarchically organized knowledge which provides a detailed description of the concept, its measurement (if appropriate), interventions used in treating patients and appropriate literature references.

These structured concepts are stored in a relational database. A system user can browse the database contents by using the concept index module, which queries the database to retrieve the information requested by a user. Also, the user may click on "hot words" in the text of a display to display a definition or additional information about an unfamiliar concept.

In addition, since the concept index identifies in a structured fashion the factors which affect patient outcome in pressure ulcer prevention, we have used the index to develop a data entry tool for recording details of the examination of the skin and comorbid risk factors for the development of pressure ulcers. In tandem, using the AHCPR guideline and other sources [9], we have developed a set of rules which characterize a patient's risk for developing pressure ulcers and which describe interventions which can treat such ulcers or help prevent their occurrence.

The system uses both patient data structured by the data entry tool and the knowledge base of expert rules to provide advice to the end user. Specifically, the Toolbook client communicates patient data to the NEXPERT server. The server in turn uses these data to fire rules in its knowledge base which determine the patient's risk for pressure ulcer and indicate interventions based on this determination. This assessment, along with appropriate explanatory text read from the concept index database, is communicated back to the Toolbook client and displayed to the user. Thus, the output of the

system consists of an assessment of risk and advice for reducing that risk. As additional guideline material for treating already extant pressure ulcers becomes available from AHCPR, we are incorporating this knowledge into the expert system knowledge base.

Further, we are encouraged by the satisfaction of our study population with the pulmonary artery catheter system and its intensely graphical user interface. The pressure ulcer domain offers many similar possibilities for graphical indexing. We have assembled a number of digitized images, including skin lesions and skin care products, and in a prototype system we have used these to help index the knowledge contained in the concept index.

As with the pulmonary artery catheter system, we plan to evaluate the impact on clinician knowledge once the system has been installed in a care unit. We also plan to evaluate its effect on patient outcome in terms of the nosocomial development of pressure ulcers.

CONCLUSIONS

We have found that the use of a graphical index to guideline knowledge permits easy and rapid access to expert knowledge. A pulmonary artery catheter waveform troubleshooting system indexed in this fashion has been accepted and found easy to use by a study population of nurses and physicians. Use of this system produced an improvement in domain knowledge in an experimental population when compared to a control group. We have extended this experience in graphical indexing through the use of a concept index in developing a computer-based system for prevention of pressure ulcers. This system permits structured entry of patient characteristics which then are processed by an expert system shell to assess risk for pressure ulcer development and to provide advice regarding risk reduction and treatment of existing pressure ulcers.

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